Effect of Finishing Density on the Physico-Mechanical Properties of Leather

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Summary

Finishing is the process in which a polymeric coating is applied in order to improve the appearance and resistance of leather products. The applications at this stage greatly affect the use and appeal of the final product. In this study, the effect of different coating compositions on the physico-mechanical properties of leather was investigated. For this purpose, three different types of finishing formulations including semi-aniline, lightly pigmented and opaque finishes having different covering powers rated from light to heavy, respectively, were applied to the leathers and results were compared with uncoated counterparts. The findings of the study revealed that the application of lightly pigmented finishing statistically increased the tensile strength, single and double edge tear loads, and stitch tear resistance of the leather to a large extent. Semi-aniline and opaque finishing gave lower or, in some cases, statistically insignificant increases in the physico-mechanical properties of the leathers.

1. INTRODUCTION

The physical and mechanical properties of leathers can vary depending on the raw material and the processing conditions used to make different types of leather such as; footwear, gloves, clothing, upholstery, saddlery, *etc.*[1] During use, leather products are exposed to many mechanical actions such as abrasion, stretching, flexing, compression as well as environmental factors like water, heat, cold, humidity, UV light, *etc.*, which the products are supposed to withstand. For this reason, besides requirements for fashionable appeal and quality manufacturing, the determination of the strength and endurance of the products to external forces are also of importance.

Leather manufacturing is a complex sequence of chemical reactions and mechanical processes amongst these, leather finishing is one of the most important stages responsible for the enhancement of the appearance of leather and defines the final performance of the products required by end-users.[2] Nowadays producers introduce more qualified products with high performance properties into the market giving increased customer satisfaction.[3] Thus, finishing has come into prominence in leather manufacturing by featuring the aesthetic qualities as well as contributing to the physical properties of leathers to meet customers' expectations.

Finishing of leather is defined as the set of operations performed to improve the appearance and surface properties the leather.[4] The coating procedure is done primarily for decorative purposes, whilst the physical properties of leathers are also affected. For instance, finishing gives a tendency to increase the rigidity of leather, while the air and water vapour permeability of the leathers are decreased.[2] These changes depend on the type of finish and finishing technology applied to leathers. The type of polymeric binder and the penetration of finishing solution into leather or the thickness of overall coating are extremely important defining the final properties expected from the leathers.[5]

The finishing formulations used may be varied depending on the type of leather and on the desired properties of the final product.[6] Among the many chemicals used in finishing formulations polymeric binders are essential for film formation on the surface and between the leather fibres as well as to adhere the pigments and other chemicals.[7] Although they form a coating film on the surface they often penetrate into the leather in base coats and adhere to the fibres to facilitate the adhesion of latter coating layers. Therefore, the layers penetrated into the leather and/or remained on the surface are expected to affect the physico-mechanical properties of finished leathers.[8]

It is well known that the physical and mechanical characteristics of leathers are mainly defined by the type and quality of raw hide/skins as well as by the chemical and mechanical operations in wet processes. However, to our knowledge a detailed study about the effect of finishing process on the mechanical properties of leathers has not been reported. In this research, three different types of finishing with a light to heavier finishing composition were applied and their effects on the mechanical properties of leathers have been investigated by various physical tests and the results were compared with unfinished leather samples.

2. EXPERIMENTAL PROCEDURES

2.1. Materials

Thirty crust chrome sheep leathers, proper for garment production, with an average of 6-6.5 square

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foot area and 0.4-0.6mm thickness were used in the research. The leathers were of the same origin and processed in the same party until the finishing process. All necessary finishing chemicals used in the formulations were supplied by Lamberti S.p.A. (Italy).

2.2. Application of finishing solutions

To evaluate the effect of finishing on the physical-mechanical properties of leathers, three types of formulations were used: semi-aniline, lightly pigmented and opaque finish. Ten different crust leathers were used for each group and each skin was cut into two equal parts from the backbone line, one part was finished and the other as control. The finishing recipes used for each group are given in Tables I-III. The application of the finishing solutions was performed using an automatic rotary spraying machine combined with a drying tunnel and the leathers were hot-plated at given intervals.

TABLE I
Semi-aniline finishing recipe

Substances	Applications 1	Applications 2	Remarks
Acrylic binder	30		1) x 3 Spray
Acrylic micro binder	50		Press: 100°C; 50 Bar
Non-ionic polyurethane	30		1) x 3 Spray
Coarse PU dispersion	40		
Oil-wax mixture	40		2) x1 Spray
Casein	40		Press: 120°C; 50 Bar
Pigment	30		
Aniline dye	30		Dry milling
Water	300	150	Toggle
Non-ionic silicone modifier	5	10	
Isopropyl alcohol	10		
Nitrocellulose lacquer		100	

2.3. Conditioning and sampling of manufactured leathers

Prior to the physical tests all finished leathers were conditioned according to standard EN ISO 2419:2012[9] and the sampling was done in accordance with the standard EN ISO 2418:2002.[10]

2.4. Physical tests

A Shimadzu AG-IS tensile testing device was used for all tests. The measurement of sample thickness was performed in accordance with EN ISO 2589:2002,[11] tensile strength and percentage extension with EN ISO 3376:2011,[12] single edge tear load with EN ISO 3377-1:2011,[13] double edge tear load with EN ISO 3377-2:2002,[14] measurement of stitch tear resistance with EN ISO 23910:2007[15] and extension set test with EN ISO 17236:2002.[16] The tensile tests were done on eight parallel samples whereas the other tests were performed with four parallel samples for each leather. During the sampling half of test pieces were cut parallel to the backbone and the other half perpendicular to the backbone.

2.5. Statistical analysis

For the statistical analysis of the results, SPSS 16.0 (SPS Inc., Chicago, USA) package program was used and the results were evaluated statistically by Duncan test in a significance level of $p<0.05$.

3. RESULTS AND DISCUSSIONS

3.1. Tensile strength and percentage extension

Tensile strength is one of the most important physical quantities of characterizing the mechanical properties of materials.[17] It is a routine quality control test in the leather industry where maximum stress and breaking elongation of leathers are determined.[18] These quality

TABLE II
Lightly pigmented finishing recipe

Substances	Applications 1	Applications 2	Applications 3	Remarks
Non-ionic polyurethane	25			1) x3 Spray
Cationic polyurethane	25			
Cationic acrylic binder	50			2) x1 Spray
Cationic oil-wax mixture	50			Press: 100°C; 50 Bar
Cationic pigment	50			
Water	200	320	150	2) x3 Spray
Non-ionic silicone modifier	5	5	10	
Isopropyl alcohol	5	5		3) x1 Spray
Acrylic binder		40		Press: 120°C; 50 Bar
Acrylic micro binder		40		
Coarse PU dispersion		40		Dry milling
Oil-wax mixture		50		Toggle
Casein		40		
Pigment		60		
Aniline dye		10		
Nitrocellulose lacquer			100	

TABLE III
Opaque finishing recipe

Substances	Applications 1	2	3	Remarks
Non-ionic polyurethane	25			1) x3 Spray
Cationic polyurethane	25			
Cationic acrylic binder	50			2) x1 Spray
Cationic oil-wax mixture	50			Press: 100°C; 50 Bar
Cationic pigment	50			
Water	200	250	150	2) x5 Spray
Non-ionic silicone modifier	5	5	10	
Isopropyl alcohol		5		3) x1 Spray
Acrylic binder		50		Press: 120°C; 50 Bar
Acrylic micro binder		50		
Coarse PU dispersion		30		Dry milling
Oil-wax mixture		10		Toggle
Pigment		60		
Aniline dye		10		
Casein		20		
Filler		50		
Non-ionic oil		10		
Nitrocellulose lacquer			100	

parameters are checked to be within the limits that are specified for different types of leathers or at the desired level of customer demand. It is thus, very important to understand, define and perform the tensile tests.[19] A high value of tensile strength is a desired property for all leather types and it is an indicator regarding the quality of leather.[20]

The tensile strength values of leather samples with the semi-aniline, lightly pigmented and opaque finishing were compared with the tensile strength values of the control groups. The average values of the control groups and the finished groups are summarized in Table IV and the distributions of the tensile strength values are given in Figure 1. When the tensile properties of the coated leathers were compared with the control groups a noticible increase was observed in average tensile strength values of all finish types (Table IV). Similarly, the values of elongation at break showed significant increase for all finished leathers. Figure 1 shows the distributions of average tensile strength values of the leathers in each group. The chart clearly shows the enhancement of the tensile strength after finish application. These results reveal that the application of a polymeric coating has a positive effect on the tensile properties of leathers. It seems that the thermoplastic polymeric coatings adhered to the leather fibres enhances the strength and the elongation of the coated material. Similar results were reported by Mohamed *et al*. where homopolymers and copolymers of styrene and butyl methacrylate were applied to leather surfaces as coating.[2] The results indicated that the physical and mechanical properties of leathers were increased for finished leathers and the improvements in the tensile strength and elongation (%) values were higher with the increase in butyl methacrylate content.

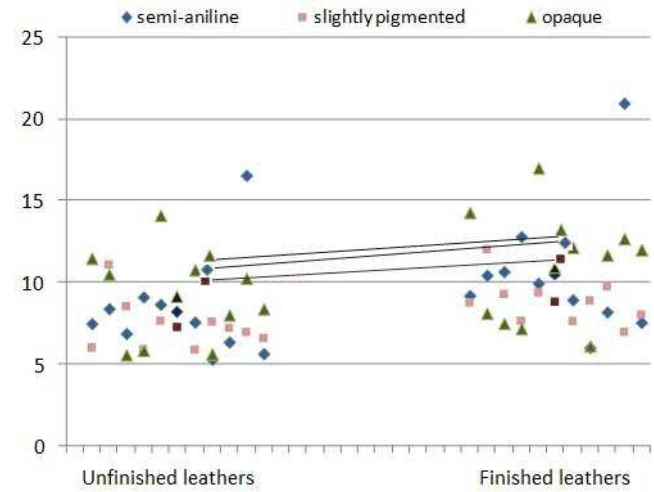

Figure 1. Tensile strength distributions of leather samples.

TABLE IV
Tensile strength of finished and control groups

Groups	Samples	Tensile strength (N/mm²)	Percentage extension (%)
Semi-aniline	Control	8.20 ± 1.01	48.50 ± 1.33
	Finished	10.48 ± 1.31	56.45 ± 1.75
Lightly pigmented	Control	7.34 ± 0.50	51.75 ± 1.64
	Finished	8.83 ± 0.45	56.24 ± 1.87
Opaque	Control	9.07 ± 0.90	47.77 ± 1.84
	Finished	10.88 ± 1.11	57.57 ± 1.53

When the results were statistically evaluated for each finish type it was calculated that the most significant increase in tensile strength was obtained for the leathers with slightly pigmented finish. The other groups of semi-aniline and opaque finished leather had lower statistical significance in the increase of tensile strength of leathers. This shows that the application of a heavier finish or in other words a thicker coating does not necessarily mean to result in higher tensile strength of the coated material. This might be possibly due to the lack of adhesion of latter finish layers that do not have enough contact with the subsrate, unfortunately we were unable to pursue this further. On the other hand, the percentage extention of the opaque finished leathers showed the highest statistical increase incomparison to the other finish types. This could be due to the higher elasticity of the polymeric coating contributed to the elongation of leather.

According to the standards by UNIDO, the suggested tensile strength value of the leathers tanned with chromium salts and handled for garment purpose is minimum 10N/mm^2.[21] Sharphouse reported that the value of 10N/mm^2 tensile strength was also a good value for the vegetable-tanned leathers.[22] UNIDO also suggested that extension value of garment leathers tanned with chromium salts should be maximum 60%. The values of tensile strength and percentage extension of the leathers in our study were similar to the recommended literature values.

3.2. Single and double edge tear loads

In a single tear test a specimen which is partially slit from one edge is pulled so that a tear is propagated from the end of the slit. In the double edge tear load test the specimen is pulled from the both edges of a specifically shaped hole in the sample. In both tests the highest force exerted during tearing is measured. Both tests give information about the mechanical strength of the leathers in the case of an applied force on a created tear on leather.

The results of tear load tests obtained from the three groups of finished leathers are given in Table V. It was obvious that finishing had a positive effect on the tear strength of the leathers since almost all maximum force values of the finished leathers were increased in comparison to the control samples. On the other hand, when the results were evaluated statistically the most significant improvement was observed for the leathers with lightly pigmented finish whereas the increase obtained from the leathers with semi aniline and opaque finish was lower and statistically insignificant. Figure 2 shows more clearly the distribution of the tear load values of the leathers for each finish type and their control groups. Excepting the decrease of average tear load values found in opaque finished leathers for single edge tear, an increase in tear load values was observed for all other finished leathers. These results clearly show that the tearing strength of the materials can be affected due to the process variation as similarly reported by Mukhopadhyay *et al.* for the tearing behaviour of military khaki fabrics from grey to finished state.[23]

TABLE V
The values of single and double edge tear loads of the finished and control groups

Groups	Samples	Edges	Tear load (N)
Semi-aniline	Control	Single edge	5.07 ± 0.59
		Double edge	9.38 ± 1.10
	Finished	Single edge	6.23 ± 0.70
		Double edge	10.76 ± 1.07
Lightly pigmented	Control	Single edge	5.17 ± 0.62
		Double edge	10.10 ± 1.05
	Finished	Single edge	8.23 ± 0.68
		Double edge	14.68 ± 1.63
Opaque	Control	Single edge	7.26 ± 0.79
		Double edge	12.45 ± 1.31
	Finished	Single edge	6.87 ± 0.57
		Double edge	13.28 ± 1.14

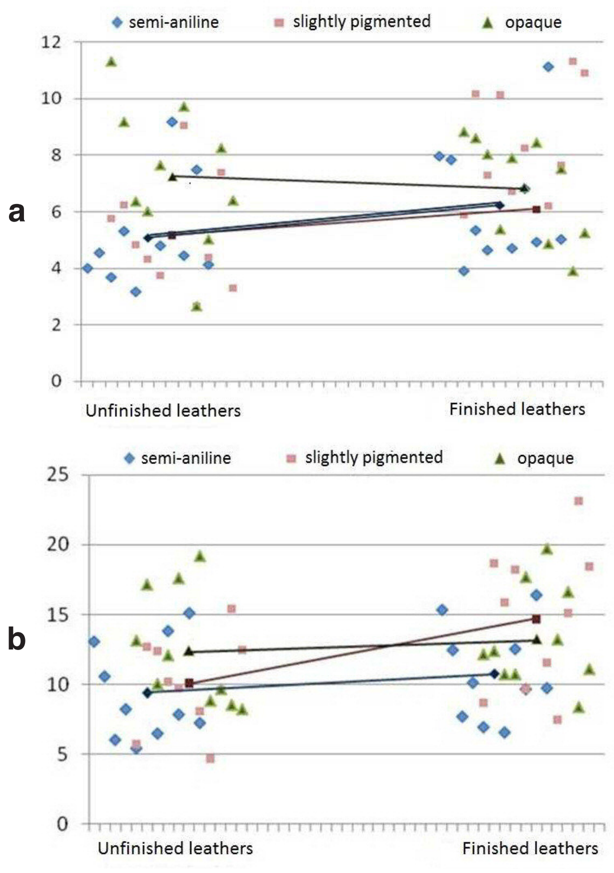

Figure 2. Distributions of single (**a**) and double (**b**) edge tear loads of the leathers.

3.3. Stitch tear resistance

In the stitch tear resistance test, a metal wire which passes through two punctures made in the leather is pulled through the material and the maximum force at break is recorded. The test gives information about the resistance of the leathers to the stress that they can be exposed to during sewing processes. Table VI and Figure 3 show the average stitch tear resistance values of the finished and control leathers. The results indicate that the resistance of leathers was highly affected by the finishing formulation applied. The semi-aniline finished leathers showed an increase in average stitch tear resistance values whereas the opaque finished leathers did not show a significant change. However, the lightly pigmented leathers exhibited almost 38% increase in stitch resistance values giving the highest improvement. This is difficult to explain, however, it seems that lightly pigmented finish formulation possibly had a better adhesion between the fibres and the surface of leather that resulted in enhanced resistance values.

TABLE VI
Stitch tear resistance values of the finished and control groups

Groups	Samples	Stitch tear resistance (N)
Semi-aniline	Control	27.28 ± 2.69
	Finished	30.53 ± 3.23
Lightly pigmented	Control	29.06 ± 3.07
	Finished	40.62 ± 4.57
Opaque	Control	34.87 ± 4.32
	Finished	34.91 ± 3.10

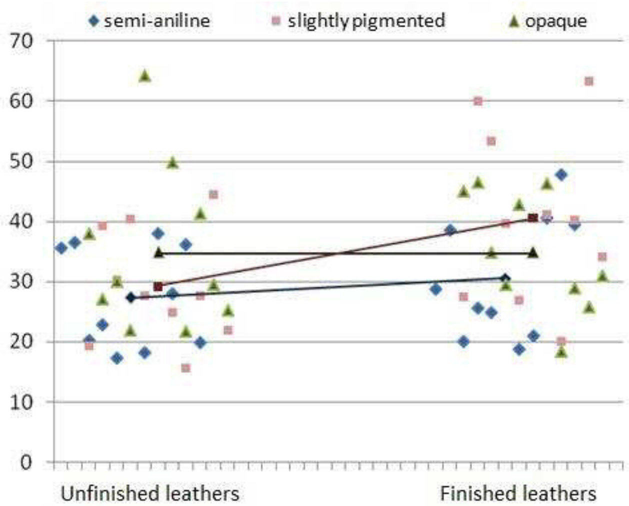

Figure 3. Distributions of the stitch tear resistance of leathers.

3.4. Extension set

The plastic deformation of the leathers was also examined by measuring the initial and final length of the specimens after a specified load applied to the leathers. The test is also important and gives information about the plastic deformation that can be occurred during the leather-making processes and/or the use of final leather product. The average extension set values of the leathers obtained from test are given in Table VII and Figure 4. It was observed that semi-aniline and slightly pigmented finishes led to a small decrease while the opaque finished leathers had slightly increased extension set values of leathers. However, the changes on extension set values were found to be statistically insignificant ($p<0.05$).

TABLE VII
Extension set values of the finished and control groups

Groups	Samples	First length (cm)	Last length (cm)
Semi-aniline	Control	18.00	20.89 ± 0.15
	Finished	18.00	20.49 ± 0.22
Lightly pigmented	Control	18.00	20.65 ± 0.21
	Finished	18.00	20.55 ± 0.26
Opaque	Control	18.00	20.89 ± 0.17
	Finished	18.00	21.07 ± 0.76

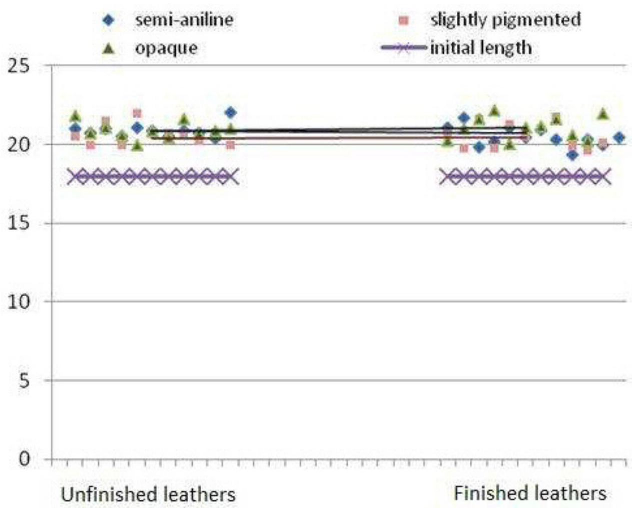

Figure 4. Extension set distributions of the leather samples.

4. CONCLUSIONS

Clients not only expect manufacturer to produce goods in the latest fashion and design but also expect them to increase the quality parameters of their products. From this view, the mechanical properties are one of the most important indicators of the quality of products because they define the behaviour of the material under many external forces and stresses created during their use. The mechanical properties of the leather products are primarily defined by the type and the quality of the raw hides/skins used for manufacture. On the other hand, the chemical and mechanical operations applied in wet processes constitute the main effect on the physical characteristics of the leathers. In the last years the decrease in the quality of raw materials increased the importance of the processes that contribute to the physical strength of leathers. Accordingly, finishing operations are also of importance for the enhancement of physical parameters of final leather products.

The present study revealed the effect of different coating formulations on the tensile strength, percentage extension, single edge and double edge tear loads, stitch tear resistance and extension set properties of leather products. The overall results showed that the density and thickness of the coating affected the mechanical properties of the leathers except the extension set behaviour. Best results were obtained from the leathers finished with a slightly pigmented formulation. Further increase in the density of the finishing application as in the case of opaque finished leathers did not result in higher strength values. This indicated that the mechanical improvement was not neccessarily related with the thickness of the coatings applied on the substrate. We believe that the partial penetration of the finishing solution through the fibres and its interaction with the surface layers are important for maximum property enhancements. The excess coating layers on the surface that do not intereact sufficiently with the leather fibres also do not contribute significantly to the mechanical properties of leathers.

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